United States Patent [19]

Andrews, Jr. et al.

[11]   **4,092,682**

[45]   **May 30, 1978**

[54]   **CROSS COUPLED DEMODULATOR FOR GENERATING A SERVO HEAD POSITION ERROR SIGNAL**

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[73]   Assignee: **Sperry Rand Corporation,** New York, N.Y.

[56]   **References Cited**

U.S. PATENT DOCUMENTS

3,292,168	12/1966	Gray	360/77
3,404,392	10/1968	Sordello	360/77
3,427,606	2/1969	Black et al.	360/77
3,534,344	10/1970	Santana	360/77
3,691,543	9/1972	Mueller	360/77
3,818,502	6/1974	Chien et al.	360/77
3,883,894	5/1975	Johnson	360/77
3,893,180	7/1975	Braun et al.	360/77

Primary Examiner—Alfred H. Eddleman
Attorney, Agent, or Firm—Gerald L. Moore

[57]   **ABSTRACT**

An improved demodulator principally for receiving dibits from a servo track and generating a position error signal responsive to the servo head position relative to the track as indicated by the dibit signal. The invention improves the capability of the demodulator to operate when noise is encountered in the dibit signal.
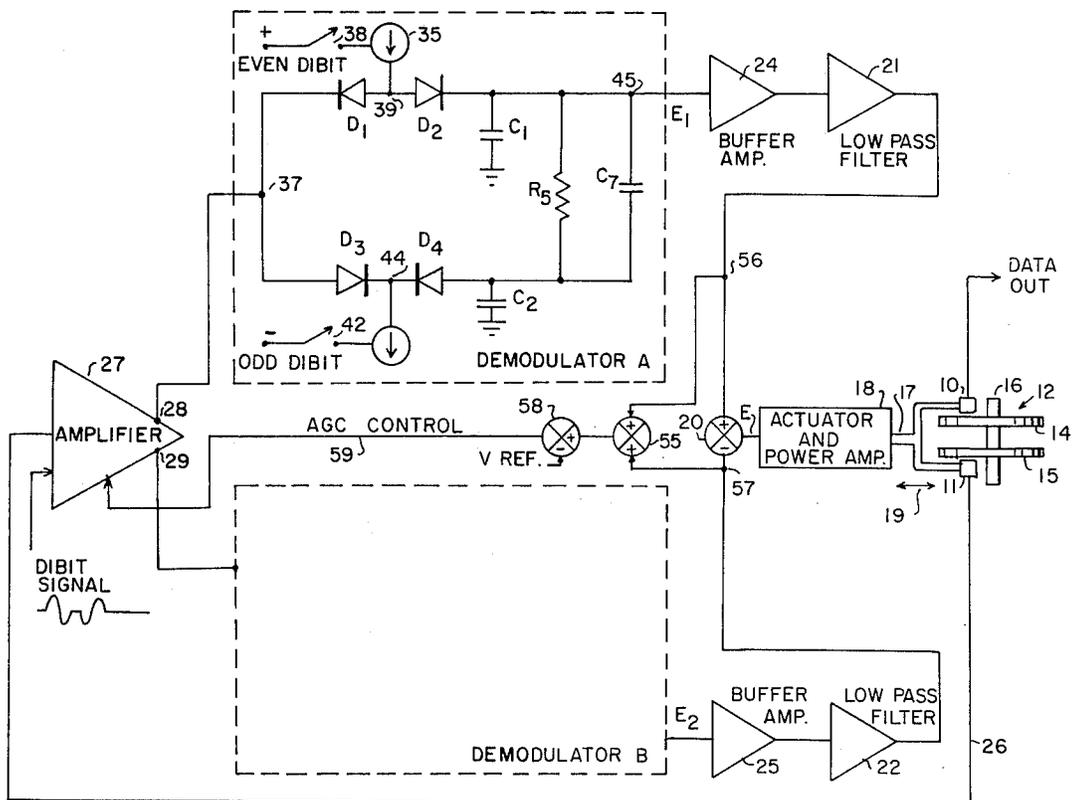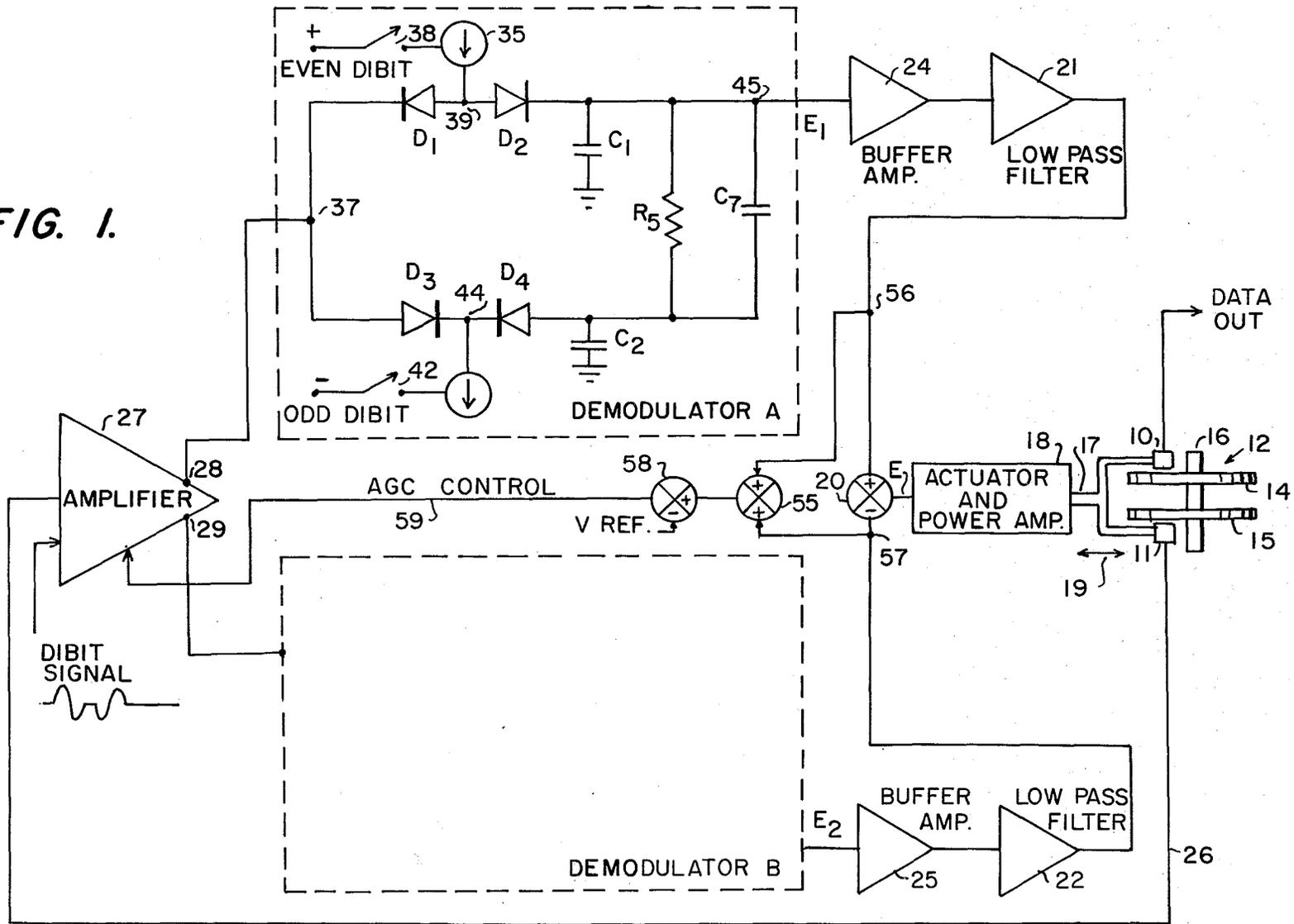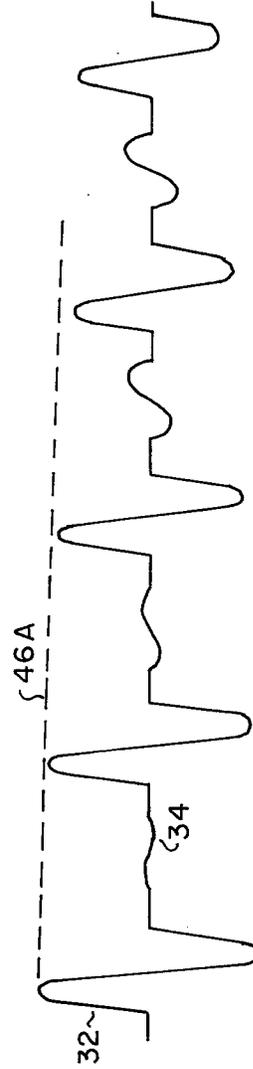
5 Claims, 10 Drawing Figures

FIG. 1.

EVEN DIBIT

+ 38 35
39 D1 D2 C1 45
R5 C7 E1
BUFFER AMP. 24
LOW PASS FILTER 21

37

D3 44 D4
42 C2
ODD DIBIT DEMODULATOR A

56

DATA OUT

AMPLIFIER 27
28
29

AGC CONTROL 58
59 V REF.
55 20 57 E ACTUATOR AND POWER AMP.
18 17 10 16 12
14
11 15
19

DIBIT SIGNAL

DEMODULATOR B

E2 BUFFER AMP. LOW PASS FILTER
25 22 26

FIG. 2A

FIG. 2B

FIG. 2C

FIG. 2D

FIG. 3
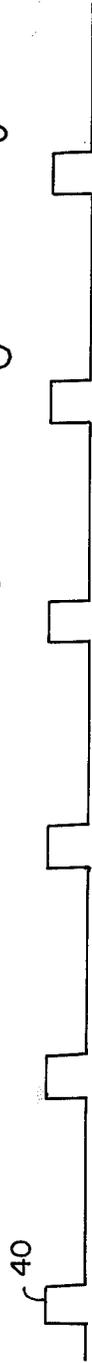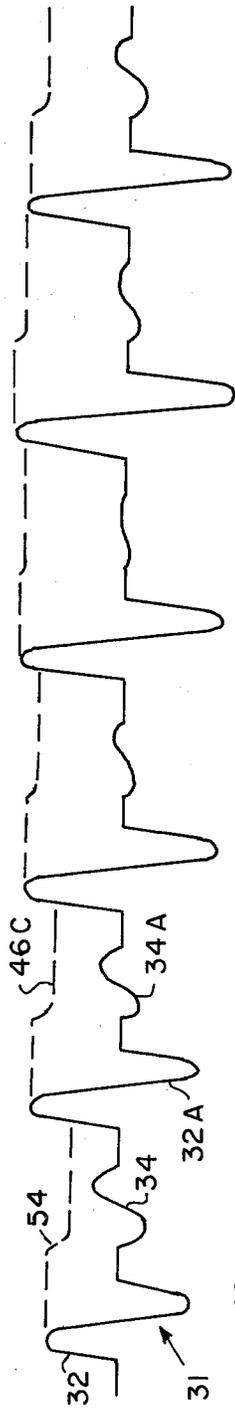
FIG. 4.

FIG. 5A

FIG. 5B

FIG. 5C

CROSS COUPLED DEMODULATOR FOR GENERATING A SERVO HEAD POSITION ERROR SIGNAL

BACKGROUND OF THE INVENTION

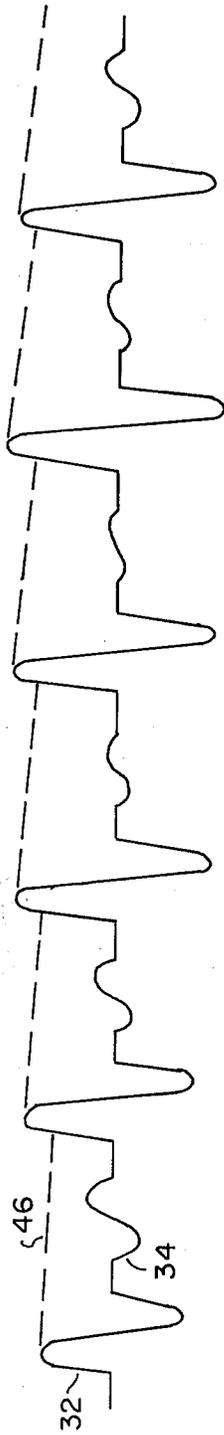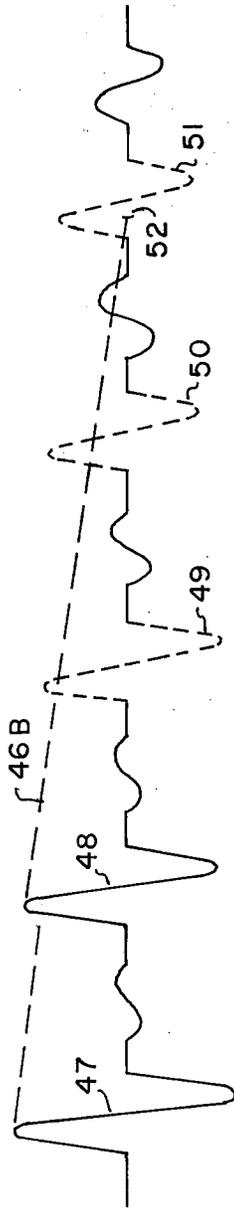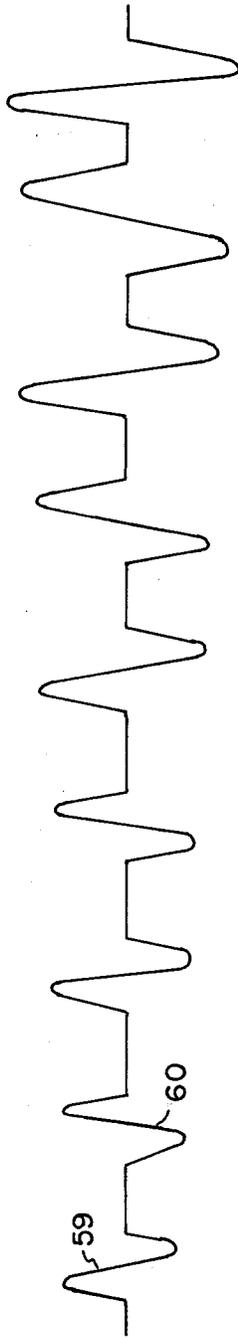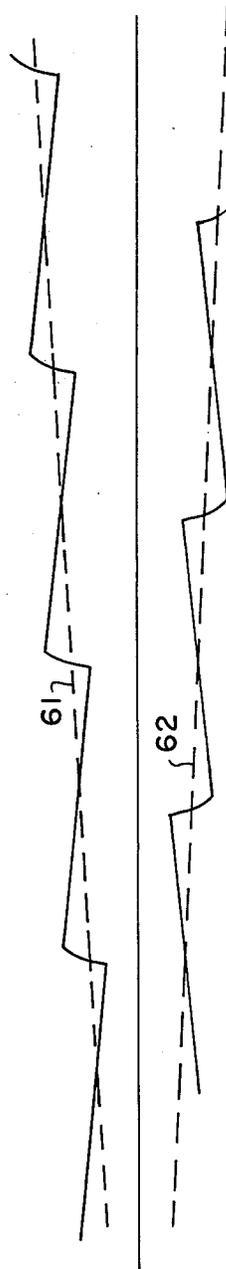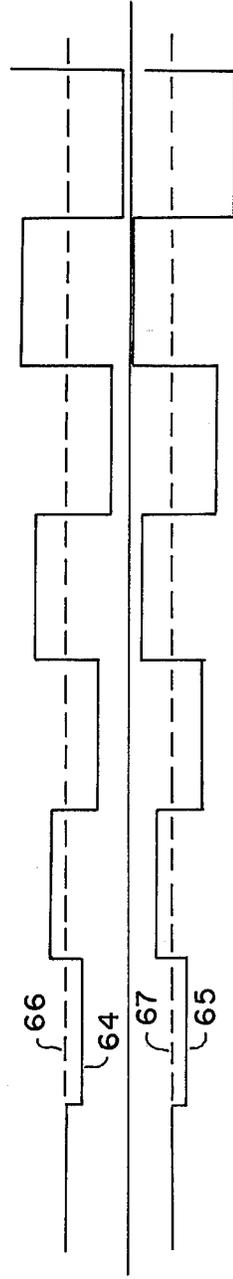This invention pertains to a servo system such as that described in the U.S. Pat. No. 3,534,344, Method and Apparatus for Recording and Detecting Information, issued on Oct. 13, 1970. In a system as described in that patent, a movable member is positioned by a servo system acting responsive to signals detected from a prerecorded servo track. The systems have particular application to disc or other types of magnetic memories for use with computers. Usually the servo head is ganged with a plurality of read/write heads for data such that when the servo head is correctly positioned over a servo track, the data heads are likewise positioned at desired data track locations. For positioning the servo head over a servo track, an error signal is generated responsive to a pair of dibit signals bordering the track. The dibit signals are recorded to each side of the servo track such that the relative magnitude of the dibit signals detected indicates the degree of alignment of the head relative to the track. These dibit signals are supplied to a demodulator for the generation of an error signal responsive to the relative magnitudes of the dibit signals detected from the servo track.

In the usual manner the demodulator functions to generate a dc output signal responsive to the peak values of the dibit signals at the side of the servo track. Such signal is caused to decay between each dibit pulse and be reset with each subsequent pulse at a value equal to the amplitude of the dibit pulse. It is necessary for the signal to decay between each pulse so as to accommodate the circumstance of the pulses becoming smaller in magnitude as the servo head moves away from that side of the servo track. Naturally the faster the servo head is being moved relative to the track, the more it is necessary for the output signal to decay so as to reach a level below the next dibit pulse magnitude and thereafter be reset higher for an accurate indication of that signal magnitude. Thus for the generation of an accurate output signal in instances of rapid change of the signal, it is necessary that the output pulse decay rapidly between dibit pulses.

However such prerecorded servo signals while having the maximum magnitude closely controlled are subject to noise commonly referred to as dropout. Such noise results from the absence of the dibit signals usually due to a flaw or discrepancy in the media preventing the servo signal from being recorded. Thus it is also necessary for the servo system to function in a manner to accommodate periodic missing dibits which result from discrepancies in the media. One method of such accommodation is to cause the output signal to decay at a slow rate between dibits so as to maintain the resulting error signal at or near the value of the most recent detected dibit which is the most accurate indication of the present position of the servo head in the absence of the subsequent dibit signal. Thus if the dibit signal is absent, the servo system will exhibit an inertial or flywheel effect to more or less maintain the servo head at the position dictated by the last servo track information supplied by the servo transducer until a dibit signal is again detected.

Thus as can be seen, the first requirement that the output signal decay rapidly is counter-productive to the

need for the servo system to accommodate noise or dropout in systems used up to now. In other words the accommodation of either one of the before-described conditions can only be achieved at the expense of the other requirement in prior systems. It is the purpose of this invention to provide a system which will accommodate both requirements, namely an output signal that will follow a quick decaying dibit signal while yet accommodating noise or dropout in the servo signal.

SUMMARY OF THE INVENTION

A servo system for positioning a movable member in alignment with a servo track formed by prerecorded dibit signals on each side of the track wherein an actuator for moving the member acts in response to an error signal. A servo head transmits the dibit signals to a demodulator for generation of an output error signal responsive to the relative magnitude of the signals. The demodulator generates first and second signals responsive to the magnitude of the dibit signals and alternately charges a pair of capacitors to the value of these signals. A third capacitor is connected across the first and second capacitors to crosscouple the circuits such that the charge on one capacitor is decreased an amount equal to the charge buildup on the other capacitor thereby serving to decay the output signal sufficiently each cycle to permit following any change in magnitude of the dibit signals.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a servo system of the type in which the improvement of the present invention can be applied;

FIGS. 2A through 2D show waveforms for the circuit of FIG. 1; and

FIGS. 3 and 4 show representative waveforms for circuits not utilizing the present invention; and

FIGS. 5A through 5C are waveforms for the circuit with and without the present invention when the dibit signals are increasing in magnitude.

DESCRIPTION OF THE INVENTION

The invention is described for use in a servo system such as that illustrated in FIG. 1 for positioning the transducers 10 and 11 relative to the disc pack 12. The disc pack comprises a pair of magnetic discs 14 and 15 on which data can be recorded. Thus as the discs are rotated about the central shaft 16 the heads are translated back and forth radially to read and record data from a series of concentric tracks on the disc surface. A motor (not shown) rotates the central shaft 16 to turn the discs.

The transducers 10 and 11 are supported on an arm assembly 17 fixed to an actuator 18 which moves the transducer and arm assembly laterally in the direction of the arrow 19. The actuator is energized by an error signal E received through the juncture 20 and supplied from the demodulators A and B through a pair of low pass filters 21 and 22 and a pair of buffer amplifiers 24 and 25, respectively. This error signal is generated responsive to a position responsive signal supplied by the transducer 11 through the conductor 26 known as the dibit signal. This signal is supplied to the amplifier 27 which supplies through the terminals 28 and 29 of the double-ended amplifier the dibit signal and the complement thereof to the demodulators A and B, respectively.

In the manner described in U.S. Pat. No. 3,534,344 identified heretofore, the dibit signals are prerecorded

on the disc 15 and comprise a plurality of circular concentric tracks forming position or data indicating reference patterns. These tracks are identified as a plurality of alternating odd and even servo tracks recorded on one surface of the disc 15. Each alternating track has a normally positive flux subject to periodically occuring sets of two flux reversals while the other alternating tracks have a normally negative flux subject to the periodically occurring sets of two flux reversals. The sets of flux reversals of the even tracks are arranged to alternate relative to the sets of flux reversals of the odd tracks.

Thus as the transducer 11 is moved into the proximity of a track it will overlap portions of the odd and even servo patterns immediately adjacent the track and transmit through the conductor 26 a resulting composite dibit signal appearing as the waveform 31 in FIG. 2A. As can be seen, the even pulses 32 are alternately interspersed with the odd pulses 34 with the relative magnitudes indicating the position of the transducer 11 and the data track bordered by the dibit patterns. Thus for the waveform FIG. 2A, the transducer 11 is positioned slightly off center and more in alignment with the even dibit pattern than the odd dibit pattern because the even dibit signal is of greater magnitude.

The dibit signal is fed to the demodulator A for the generation of a dc output signal responsive to the magnitude of the even pulses. For this purpose the demodulator comprises a current source 35 connected to supply current through the diodes D_1 and D_2. Similarly a current source 36 is connected to transmit current away from the circuit through the diodes D_3 and D_4. These diodes D_1 and D_2, D_3 and D_4 are connected to regulate the charge on the charge accumulators or capacitors C_1 and C_2. Thus the capacitor C_1 is charged each cycle to the amplitude of the even pulse and the capacitor C_2 is charged each cycle to the amplitude of each odd pulse.

To explain the operation of the demodulator, as the initial pulse 32 is fed to the terminal 37 of the demodulator A, the diode D_1 is back-biased and the diode D_2 is forward-biased by the resulting voltages thereacross. Thereafter is fed to the switch 38 a pulse signal 40 (FIG. 2C) from a source not shown and timed with the occurrence of the first half cycle of the even dibit as illustrated in FIG. 2C. This pulse 40 serves to close the switch 40. With the switch 38 closed, the current source 35 is caused to transmit current to the terminal 39 which because of the previously-described biases on the diodes D_1 and D_2 serves to charge the capacitor C_1 until the charge on that capacitor is equal to the magnitude of the even pulse. At that occurrence D_2 will become non-conductive and D_1 will become conductive. Thereafter the pulse 40 ceases and with the occurrence of the first half-cycle of the odd pulse 34, a pulse 41 occurs (FIG. 2D) serving to close the switch 42 connecting with the current source 36 to conduct current from the terminal 44. The resulting voltages will forward bias the diode D_4 so that current flows through the switch 42 until the charge on the capacitor C_2 reaches that of the magnitude of the negative dibit pulse at which time the diode D_4 will become nonconductive. In the manner just described the capacitors C_1 and C_2 are charged alternately to the magnitudes of the even and odd dibit pulses, respectively.

Thus there will be generated at the terminal 45 a voltage signal similar to that illustrated by the dotted line 46 in FIG. 2B representative of the charge on capacitor C_1 and responsive to the magnitude of the even

dibit pulses. It will be noted that between pulses there is a sag in the magnitude of this dc signal because of the current drain through the circuit including the resistor R_5. Such a sag or slew rate is necessary to decrease the magnitude of the dc output signal so that as the magnitude of the dibit pulses decreases, the resulting output signal follows that decrease in amplitude to render an accurate output signal. The demodulator B operates in the same manner and incorporates the same circuitry as demodulator A. However the dibit signal supplied to this demodulator is of opposite polarity such that the output signal, in being subtracted from the output signal of demodulator A will serve to cancel out most inaccuracies due to errors, etc. in operation of the circuits because of the components used therein. The low pass filters 21 and 22 tend to smooth out the output signals to generate average value signals approximately the amplitude of the even pulses.

As pointed out before, for purposes of more closely approximating the maximum value of the even pulses, it would be desirable for the resistor R_5 to be of high value so that the sag or slew rate between pulses is slight. This would mean that the average value for the signal 46 would be very close to the peak value of the even dibit pulses. However as illustrated in FIG. 3, if the slope is sufficiently slight and the magnitude of the even going pulses is decreasing as would occur as the transducer moves away from that dibit pattern, the waveform 46A will not follow the peaks of the dibit pattern but instead will render an erroneous signal not responsive to the relative position of the transducer and the even dibit pattern. Thus it is necessary that the resistor R_5 be sufficiently small to permit the slew rate to be sufficiently large to at least follow the decrease in magnitude of the even dibit pulses.

However as also was pointed out before, another problem with prerecorded servo tracks is noise, that is, while the magnitude of the pulses can be closely controlled, still there always remains the possibility of dropout, i.e., the loss of the dibit pattern. Such is illustrated in FIG. 4 wherein the even dibit pulses 47 and 48 are followed by the lack of dibit pulses which are illustrated by the dotted lines 49, 50 and 51. In other words in the servo pattern, no dibit pulses are detected by the transducer 11 for a period of time. Now it can be seen that the signal 46B in FIG. 4 continues to sag in the absence of dibit pulses and can give a more erroneous indication of the relative position of the transducer and the dibit pattern as indicated by the difference in magnitude at point 52 between the waveform 46B and what would be the magnitude of the error signal if it followed the peak of the dibit signal 51 at that point. Under these circumstances the transducer will be actuated to a new position based on the erroneous signal resulting from the circumstance that no even dibit pattern is being sensed. Thus it can be seen that while a faster slew rate is desired when the change in magnitude of the dibit signals is greater as occurs when the head is moved rapidly across the servo tracks, still too great a sag in the presence of noise will result in the generation of an erroneous error signal also. Past demodulators have attempted to compromise the slew rate to accommodate these circumstances, with the results being less optimum at the least.

In accordance with the present invention and as illustrated in FIG. 1, the capacitors C_1 and C_2 are cross-coupled by a third capacitor C_3. Preferably this third capacitor has a capacitive value 100 times or more that of

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either of the capacitors C_1 and C_2 which preferably are of equal value. With the cross-coupling of the capacitors C_1 and C_2, the magnitude of the odd pulse is subtracted from the magnitude of the dc error signal each cycle at a point between even dibit pulses. As shown in FIG. 2B, with the occurrence of the first odd pulse 34 a reduction in the amplitude of the output signal 46C is effected at the negative slope portion 54. Subsequently with the occurrence of the following odd pulse 34A, there is a similar reduction in the overall magnitude of the dc output signal after it has once again been increased to the magnitude of the even pulse 32A.

Thus it can be seen that in the ranges where the pulses are changing little in magnitude, there is also little change effected by the cross-coupling. However where the maximum amplitude of the pulses are changing rapidly, there is just as rapid a slewing or pulldown of the output signal between the peaks of the even pulses being detected. Of course in actuality these magnitudes change less between cycles than that shown in the drawings since the drawings are made to emphasize the overall operation of the invention.

In addition, with the absence of any even dibit signal, the larger capacitor C_3 serves to maintain the signal near a constant value with little sag. This noise or dropout is accommodated just as satisfactorily as a fast change in the amplitude pulses.

In FIGS. 5A through 5C is illustrated another advantage of the present invention. Normally there is provided an automatic gain control circuit as shown in FIG. 1. This circuit comprises a juncture 55 into which are fed the averaged error signals from the demodulators A and B and detected at the terminals 56 and 57. The sum of these error signals is compared to a predetermined signal V_{ref} at the juncture 58 with the differential signal being fed to the amplifier 27 through the conductor 59 for control of the gain.

However this circuit is relatively slow acting, since to supply components capable of rendering instantaneous response would require expensive components. One situation for which the gain control just described will not always compensate for is the instance of both dibit signals 59 and 60, odd and even, increasing in strength concurrently as shown in FIG. 5A. Such can occur for instance, when the recording media in the disc 15 is increased in thickness. As shown in FIG. 5B, both filtered signals 61 and 62 from the demodulators increase as illustrated by the dashed line thereby affecting other circuits such as a tachometer responding to the dibit signals.

However as shown in FIG. 5C the error signals 64 and 65 because of the cross-coupled circuits, tend to compensate for this occurrence. Such occurs because the signals resulting are both increased in magnitude and since one signal is subtracted from the other, the resulting signals 66 and 67 remain substantially unchanged. Thereafter the automatic gain circuit will function to reduce the magnitude of the dibit signals.

The invention claimed:

1. A servo system for positioning a movable member in alignment with a servo track formed by prerecording

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cyclic dibit signals to each side of the track, said system comprising, in combination:

an actuator for positioning said movable member responsive to an error signal;

a servo head for detecting said prerecorded dibit signals;

a demodulator for receiving said dibit signals from the servo head and generating an output error signal responsive to the relative magnitude of the two dibit signals one to each side of the servo track, said demodulator comprising

means to generate a direct current signal having a magnitude responsive to the magnitude of each dibit signal and

means to reduce the magnitude of each direct current signal by a magnitude proportional to any change in magnitude of said other direct current signal to assure that each direct current signal is responsive to the corresponding dibit signal.

2. A servo system as defined in claim 1 wherein said direct current signal is reset in magnitude during each cycle of said dibit signals.

3. A servo system as defined in claim 2 wherein said means to generate a direct current signal comprises first and second capacitors and a current source for each dibit signal in combination with means to charge each capacitor responsive to the magnitude of one of the dibit signals.

4. A servo system as defined in claim 3 wherein said means to reduce the magnitude of each direct current signal comprises a third capacitor connected between the terminals of said first and second capacitors.

5. A servo system for positioning a movable member in alignment with servo track formed by prerecording dibit signals to each side of the track, said system comprising, in combination:

an actuator for positioning said movable member responsive to an error signal;

a servo head for detecting said prerecorded dibit signals;

a demodulator for receiving the dibit signals and generating an output error signal responsive to the relative magnitude of the two dibit signals, said demodulator comprising:

means for generating first and second dc signals responsive to the magnitude of each of said dibit signals;

first and second charge accumulator means each having first terminals for receiving and storing said first and second dc signals respectively;

means for generating an error signal for energization of said actuator responsive to the relative magnitudes of said first and second dc signals; and

a third charge accumulator connected between said first terminals of the first and second charge accumulators for cross coupling the first and second charge accumulators such that an increase in the charge of either the first or second accumulator will result in a reduction in the charge of the other charge accumulator.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO.   :   4,092,862
DATED   :   June 6, 1978
INVENTOR(S) :   Allen L. Taylor

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[63] Change May 4, 1976 to -- May 6, 1974 --.

Column 1, line 5, change "May 4, 1976" to -- May 6, 1974 --.

Signed and Sealed this

Thirteenth Day of February 1979

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

DONALD W. BANNER
Commissioner of Patents and Trademarks